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(54) Hydraulic brake system for motor vehicles having an anti-skid control device

(57) The system includes a master brake cylinder 1 filled with a first pressure medium and acted upon mechanically by a hydraulic brake force booster 2 operated by a second pressure medium and operable as a pressure modulator for the anti-skid control, a shut-off valve 61–64 being provided in each of the brake lines 13, 14 leading from the master cylinder to the wheel brake cylinders. In order to minimize the reactions of a control pedal occurring during pressure modulation, modulation during anti-skid control is produced by working piston 22 of the booster 2 on the one hand and, on the other hand, by a modulation element 4 which is independent thereof, the pressure modulation being effected substantially exclusively by the modulation element 4 in the case of an average range of modulation and with the working piston 22 retained in its axial position, and the working piston 22 being axially displaced to modulate the pressure in conformity with the control requirements only when larger pressure changes are required. As shown the modulation element 4 is a piston-cylinder unit separated from the brake booster 2. In Fig. 2 the element is an auxiliary piston (5) in the booster 2. A valve unit 7 of the anti-skid control device controls the modulation—various valve connections and operations are disclosed.

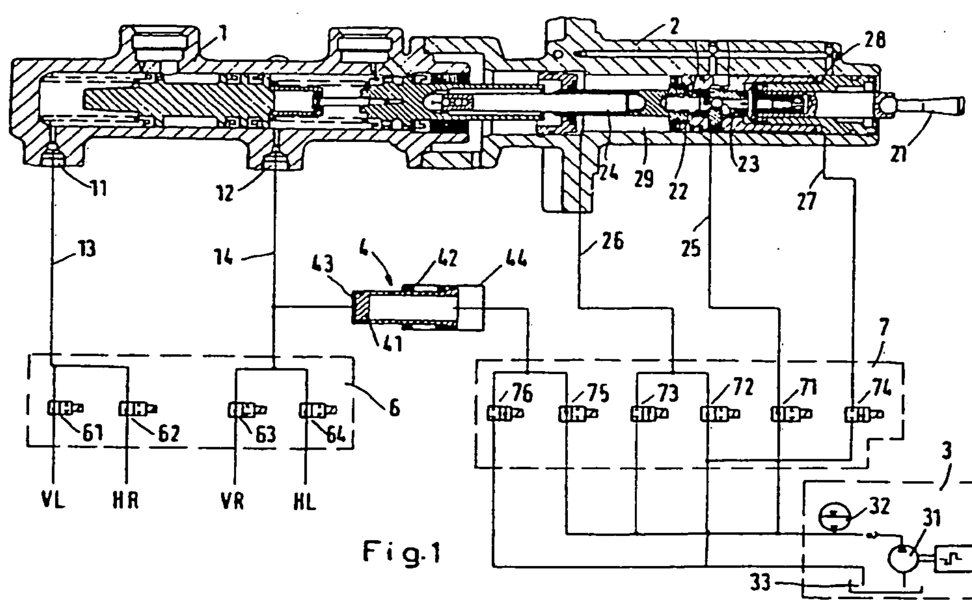

Fig.1

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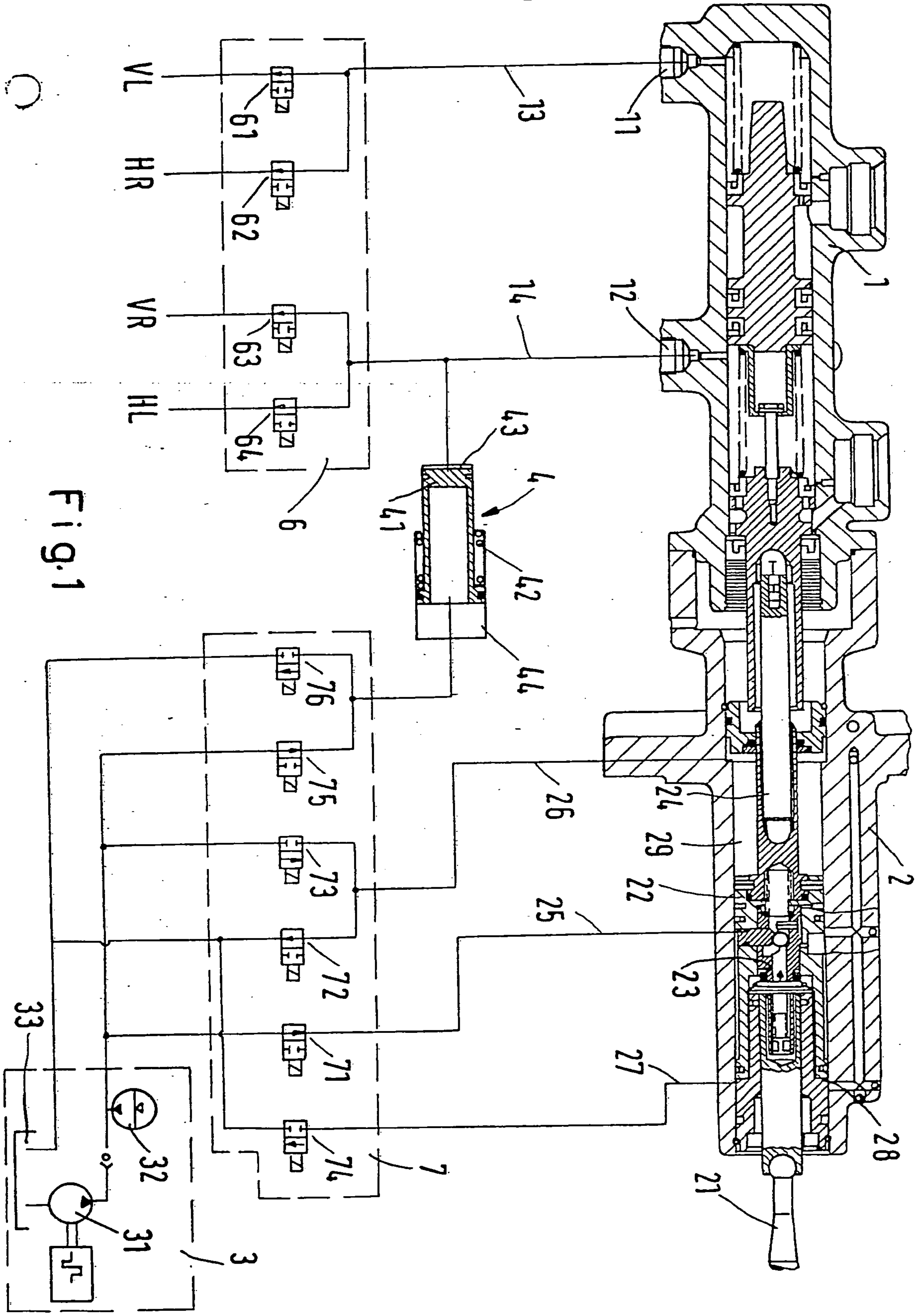

Fig.1

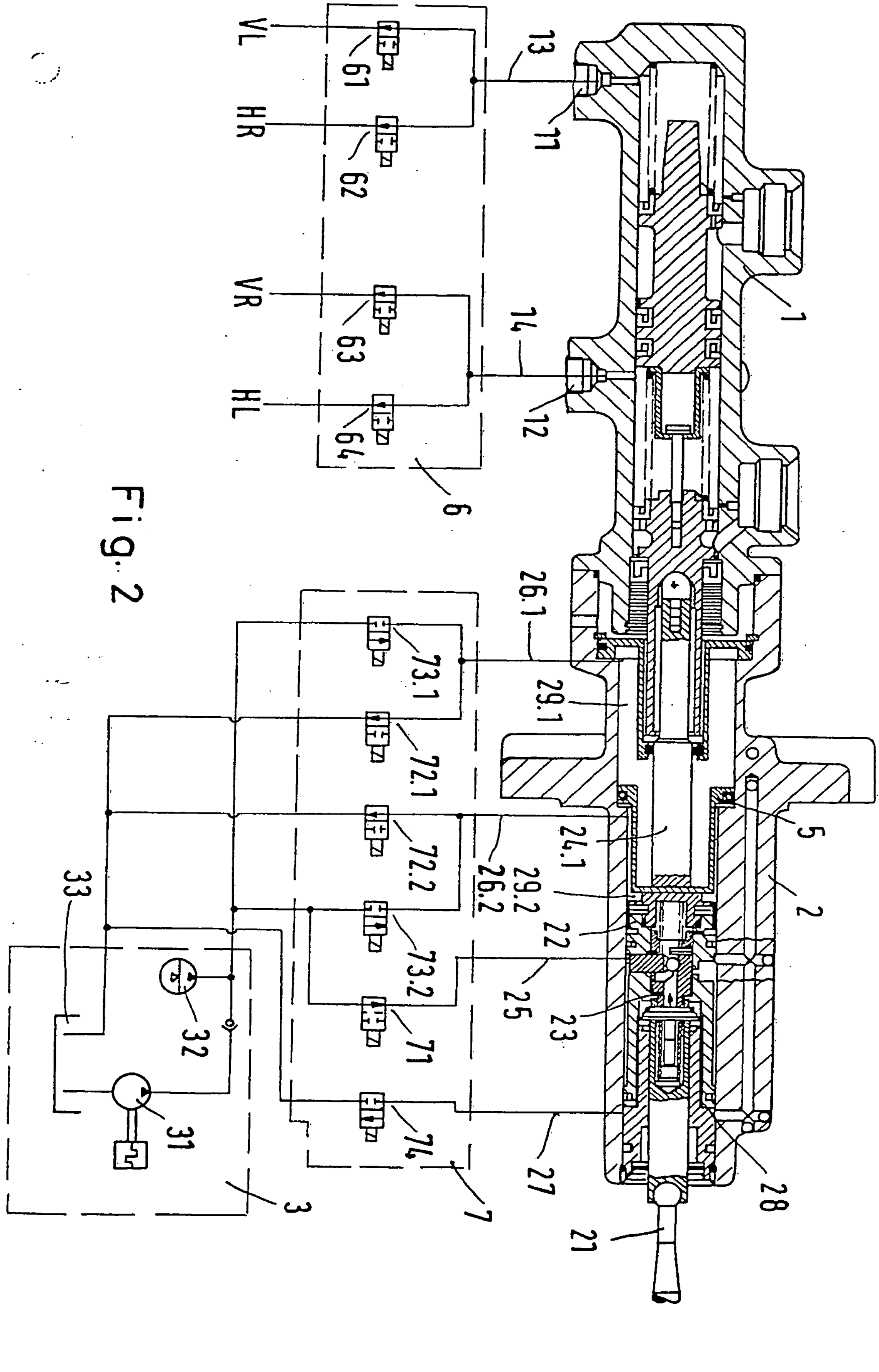
VL
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Fig. 2

SPECIFICATION

Hydraulic brake system for motor vehicles having an anti-skid control device

The invention relates to an hydraulic brake system for motor vehicles, having an anti-skid control device. More specifically it concerns such systems of the type disclosed in German Offenlegungsschrift No. OS 33 22 786.

Such known brake systems can be constructed with low pressure brake force boosters or vacuum brake force boosters as well as with hydraulic brake force boosters.

Compared with other anti-skid-controlled brake systems having hydraulic brake force boosters, the use of the hydraulic brake force booster as a pressure modulator, has the advantage that, on the one hand, there is no necessity for a valve outlet from the controlled brake circuits to a reservoir for the control function "reduction of pressure", this being especially significant from the viewpoint of safety, and that, on the other hand, the energy supply (pressure accumulator, pump or the like, which in any case has to be provided in the servo circuit of the brake force booster, may be used for the control function "build-up of pressure". Since hydraulic brake force boosters (servo circuits) and master brake cylinders (brake circuits) are operated, inter alia, with different pressure media, for example with mineral oil on the one hand and with brake fluid on the other hand; it would not be possible to utilize this energy supply directly by feeding from the brake force booster into the brake circuits.

When the working piston of a brake force booster is used directly for pressure modulation within the scope of anti-skid control, the travel of the thrust rod must always be proportional to the prevailing volume requirement of the wheel brake cylinders of the controlled brake circuits. Varying conditions of the roadway, such as "μ-Sprung" or "μ-Split" (abrupt changes in the coefficient of friction of the roadway or different coefficients of friction at the nearside and offside wheels), can lead to considerable pressure transients and hence to correspondingly long pedal travel, this being extremely unpleasant and presenting difficulties for the driver of the vehicle.

An object of the invention is to construct a brake system of the type specified, with the retention of its media separation betwe n th servo circuit on the one hand the brake circuits on the other hand, in such a way that thereaction pedal remains relatively small and stable during the pressure modulation taking place within the scope of anti-skid control.

According to the present invention then, in an hydraulic brake system for motor vehicles having an antiskid control device, comprising a master brake cylinder operated by a first pressure medium, and a brake force booster which acts mechanically upon the master brake cylinder and which is operated by a second pressure medium and is operable as a pressure modulator for the anti-skid control, a respective shut-off valve being provided in each of the brake lines leading from the master brake cylinder to the wheel brake cylinders, (a) the brake force booster is an hydraulic brake force booster having a pressure line connection which is connectible to an hydraulic pressure source, and at least one return-flow line connection which is connectible to a reservoir and which additionally has an auxiliary connection connected to its working chamber (b) the pressure modulation during anti-skid control is produced on the one hand by the working piston of the brake force booster and, on the other hand, by a modulation element which is independent thereof, (c) in case of an averaqe range of modulation (magnitude of the changes in pressure), the pressure modulation is substantially exclusively effected by the modulation element, while the working piston is retained in its axial position in such a way that it is not displaceable in a direction to build up pressure, and (d) in the case of greater than average changes in pressure which may be required, the working piston is also axially displaceable in conformity with the control requirements.

The modulation element may be a piston and cylinder unit which is separate from the brake force booster and whose axially displaceable piston sub-divides a cylindrial chamber into a modulation chamber which is filled with the first pressure medium and which communicates with one of the brake circuits fed by the master brake cylinder, and a working chamber which, in conformity with the control requirements, is connectible either to the pressure source or to the reservoir by way of a respective shut-off and opening valve. Alternatively the modulation element may be an auxiliary piston which is subjectable to pressure at both ends and which, disposed within the return-flow chamber of the brake force booster to sub-divide the said return-flow chamber into a first and a second component chamber, is rigidly secured to the thrust rod which is effective between the working piston of the brake force booster and the master brake cylinder and which is separate from but abuts axially against the working piston.

Hence, in accordance with the invention, the working piston of the hydraulic brake force booster is not permanently and directly effective as a pressure modulator within the scope of the anti-skid control during pressure modulation, but only when larger pressure changes are required. On the other hand, a special modulation element, which is independent of the working piston, whether as an external construction or an unconnected auxiliary piston in the brake forc booster, is effective during normal pressure modulation with an average

range of modulation (average pressure changes), while the working piston is substantially decoupled from the actual pressure modulation. The reactions of the pedal occurring during pressure modulation are reduced to such an extent by these measures that they are no longer troublesome to the driver of the vehicle on the one hand, although, on the other hand, they clearly signal to him the commencement of the anti-skid control.

The invention will now be further explained by way of examples with reference to the accompanying drawings, which show two embodiments diagrammatically and partially sectioned. In the drawings:

Fig. 1 illustrates a first embodiment of a hydraulic brake system in accordance with the invention, having a special modulation element disposed outside the brake force booster, and

Fig. 2 shows a second embodiment of a brake system of this kind, having a special modulation element disposed within the brake force booster.

The drawings only show those components of a hydraulic brake system for motor vehicles with an antiskid control device which are necessary for understanding the invention. Hence, for example, the brake pedal, the compensating reservoir of the master brake cylinder, the wheel brake cylinders and sensors for detecting the rotational speed and/or rotational deceleration values of the vehicle wheels, and the actual electronic control and regulating device of the anti-skid control device, are not illustrated.

In the two embodiments, a master brake cylinder 1 in the form of a tandem master brake cylinder, and an hydraulic brake force booster 2, are axially interconnected in a conventional manner, the brake force booster acting mechanically upon the master brake cylinder 1 by way of a thrust rod 24 (Fig. 1) or 24.1 (Fig. 2).

With respect to its booster properties, the internal construction of this hydraulic brake force booster corresponds to conventional hydraulic brake force boosters disclosed in, for example, German Patent Specification No. D 29 28 985 or No. D 30 23 027. It includes, inter alia, a working piston 22 axially displaceably guided in the valve housing, and a control spool 23 axially displaceably mounted in a blind axial bore in the working piston. Displacement of the control spool within the working piston by means of an actuating rod 21 connected to the pedal (not illustrated) connects a working chamber 28, defined by that end face of the working piston having the blind bore into which the control spool is inserted, either to a pressure line connection 25 or to a return-flow line connection 26 (Fig. 1) or 26.2 (Fig. 2) according to the position of the control spool relative to the working piston, by way of axial and radial openings (not designated) in those parts. The return-flow chamber of the brake force booster is designated 29.

In contrast to conventional hydraulic brake force boosters, the brake force booster 2 additionally has an auxiliary connection 27 which communicates with the working chamber 28, hence providing additional possibilities with respect to control technology.

Since the brake force booster is operated as a pressure modulator within the scope of the anti-skid control of the hydraulic brake system, its line connections are not connected directly to the pressure medium supply 3 as in the case of conventional arrangements, but are connected thereto by way of a first valve unit 7, the pressure medium supply comprising, on the one hand, a pressure source comprising a pump 31 and a pressure accumulator 32 and, on the other hand, a reservoir 33.

In order to minimize reactions of the pedal during anti-skid control, a modulation element, which is independent of the working piston, is provided and, in the embodiment of Fig. 1, is a piston and cylinder unit 4 separated from the brake force booster 2. The brake force booster 2 and the modulation element 4 are constructed and controlled in such a way that, with an average range of modulation, that is to say, with average pressure changes, the pressure modulation required during anti-skid control is produced substantially exclusively by the modulation element 4, while the working piston 22 is retained in its axial position in such a way that it is not displaceable in a direction for the build-up of pressure. It is only when larger pressure changes are required that the working piston 22 is also axially displaced for pressure modulation in accordance with the control requirements.

The piston and cylinder unit 4 includes an axially displaceable piston 41 which sub-divides the cylindrical chamber of this unit into a modulation chamber 43 and a working chamber 44. The modulation chamber 43 is filled with the same pressure medium with which the master brake cylinder 1 is filled, and is connected to one of the mutually independent brake circuits 13 or 14 which are fed from the master brake cylinder 1 by way of the latter's outlets 11, 12 respectively. On the other hand, the working chamber 44 is filled with the same pressure medium with which the servo circuit, that is to say, the hydraulic brake force booster, is filled, and, according to the control requirement, may be connected either to the pump 31 or the pressure accumulator 32 or to the reservoir 33 by way of a shut-off valve 75 or opening valve 76 respectively on the first valve unit 7. In the illustrated state ready for operation, the working chamber 44 communicates with the pump 31 by way of the shut-off valve 75, whereby the piston 41 is held against the action of a spring device 42 in a position in which the modulation chamber 43 has its smallest vol-

ume. It may readily be seen that the volume of the modulation chamber 43 may be vari d between a minimum volume (as illustrated) and a maximum volume by corresponding change-over of the two valves 75 and 76, which results in corresponding changes in the brake pressure, namely in the two circuits, since the pressure changes directly effected in the brake circuit 14 by means of the modulation element 4 have the same effect in the brake circuit 13 by way of the piston of the tandem master cylinder. However, corresponding effects would not occur if a so-called twin cylinder were used instead of the tandem cylinder used in the embodiment.

The anti-skid control device of the brake system, whose sensors and electrical control device and regulating device are not further illustrated, includes, in addition to the aforementioned first valve unit 7, a second valve unit 6 comprising shut-off valves 61 to 64. The shut-off valves 61 to 64 are disposed in the respective brake lines leading to the wheel brake cylinders of the individual wheels VL, (front left), HR, (rear right), VR (front right), and HL (rear left) of the vehicle and, in accordance with the control requirements, may be changed over individually or commonly from their illustrated open state into a closed state, in which the brake pressure in the wheel brake cylinders connected downstream of the valves is held at the value prevailing at that time.

The first valve unit 7 includes, in addition to the valves 75 and 76 already mentioned, four further shut-off and opening valves 71 to 74. The shut-off valve 71 is disposed in the line leading from the pressure line connection 25 and from the return-flow line connection 26 to the pressure medium supply 3, whilst the valves 71 and 73 are disposed in the lines leading to the pump 31 or to the pressure accumulator 32, and the valve 72 is disposed in a line leading to the reservoir 33. These three valves are illustrated in their switching states particularly during normal operation, that is to say, in the range of partial braking in which anti-skid control has not yet commenced, so that the pressure line connection 25 and the return-flow line connection 26 are connected to the pressure source and to the reservoir respectively in the usual way. The opening valve 74 is disposed in the line leading from the auxiliary connection 27 to the reservoir 33.

When required, that is to say, when there is the risk of wheel lock, the valves of the two valve units 6 and 7 are controlled by the electronic control and regulating device of the anti-skid control device in such a way that, corresponding to the control requirements, "pressure holding", "reduction of pressure" and "build-up of pressure" take place in the individual brake lines in a known manner, this pressure modulation normally being effected substantially exclusively by the piston and cylinder unit 4.

Upon commencement of an anti-skid control cycle, the valves of the first valve unit 7 are controlled by the electronic control and regualting device of the anti-skid control device in such a way that the working piston 22 cannot be further displaced from the axial position it has just assumed, with respect to travel, in a direction to build up pressure (no further to the left as viewed in the drawings), that is to say, it assumes a "pressure holding" position. This may be effected by, for example, switching the shut-off valve 72, by itself or together with the shut-off valve 71, into its shut-off position. By mutual change-over of the valves 75 and 76, the pressure in the brake circuits 13 and 14, commencing from the prevailing pressure, can then be alternately further reduced and built up to this value again by means of the modulation element 4.

The magnitude of the pressure changes obtainable by the modulation element 4 depends upon the magnitude of the potential change in volume of the modulation chamber 43 of that element. In normal circumstances, that is to say, with substantially uniform and constant conditions of the roadway, the pressure modulation producible exclusively by means of the modulation element 4 is adequate for reliable and satisfactory anti-skid control, even with a modulation element of relatively small dimensions.

However, with very great changes in the conditions of the roadway (μ-Sprung) or vertical movement, or with greatly varying conditions (sideways between right and left, (μ-Split), variations by drops in pressure and subsequent rises in pressure, greater than those which can be produced by the modulation element, may be necessary during anti-skid control. In such a case, the valves 71 to 74 of the first valve unit 7 are controlled by the electronic control and regulating device of the anti-skid control device in such a way that the working piston 22 is displaced axially in one direction or the other direction in conformity with the control requirements for the purpose of assisting the modulation element 4.

The reactions of the pedal are greatly reduced by the measures taken. The remaining reaction of the pedal will be slightly more perceptible only when the μ-conditions of the roadway change to a considerable extent.

The construction and mode of operation of the embodiment illustrated in Fig. 2 are substantially identical to those illustrated in, and explained with reference to Fig. 1. In this respect, the same components have been provided with the same reference numerals.

In contrast to the embodiment illustrated in Fig. 1, however, the special modulation element acting independently of the working piston 22 of the brake force booster 2 is not constructed as an element which is separate

from the brake force booster, but is integrated into the brak force booster. It is formed by an auxiliary piston 5 which is nan-deformably secured, within the return-flow chamber of the brake force booster, to the thrust rod 24.1 effective between the working piston 22 and the master brake cylinder 1. The auxiliary piston 5 sub-divides the conventional return-flow chamber of the brake force booster into a first and second component chamber 29.1 and 29.2 respectively. Correspondingly, the brake force booster has two return-flow line connections 26.1 and 26.2 respectively.

In contrast to other practices, the thrust rod 24.1 is not rigidly connected to or integral with the working piston, but only abuts axially and loosely thereagainst, so that, although the servo force of the brake force booster is transmissible by working piston 22 to the thrust rod 24.1, the thrust rod can also be moved axially by the auxiliary piston 5 which is subjected to pressure at both ends.

In the second embodiment, as in the embodiment of Fig. 1, the outlets 11, 12 of the master brake cylinder 1 are connected to the associated wheel brake cylinders by way of shut-off valves 61 to 64 of a second valve unit 6. The line connections 25, 26.1, 26.2 and 27 of the brake force booster 2 are likewise connected to the pressure medium supply 3 by way of an interposed first valve unit 7 of the anti-skid control device. A valve arrangement identical to that of the embodiment of Fig. 1 has been chosen, although the two shut-off and opening valves 72.1 and 73.1 are not connected to the working chamber of an external modulation element, but are connected to the return-flow line connection 26.1 which communicates with the second return-flow chamber 29.1.

The essential function of the arrangement illustrated in Fig. 2 is identical to that of the arrangement illustrated in Fig. 1, that is to say, with an average range of modulation, the pressure modulation required during anti-skid control is effected chiefly by a modulation element which is independent of the working piston, namely by the auxiliary piston 5, while the working piston 22 is used for pressure modulation essentially only when particularly large pressure changes have to be produced during pressure modulation as a result of corresponding characteristics of the roadway.

However, as a result of the differing construction and arrangement of the modulation element, the auxiliary piston 5 in the present case, there are some differences in the mode of operation of the arrangement. Hence, upon commencement of an anti-skid control cycle, the valves of the first valve unit 7 are not controlled by the lectronic control and regulating device in such a way that the working piston 22 immediately remains substantially in the axial position which it has just assumed. Rather is the working piston 22, together with the auxiliary piston 5, pushed back in an axial direction (to the right as viewed in the drawing) for as long as the control requirement "reduction of pressure" exists for the anti-skid control device, until the electronic control and regulating device prescribes the control requirement "build-up of pressure". By corresponding control of the valves of the first valve unit 7, the working piston 22, and hence the pedal connected thereto, remains in the axial position is has assumed at this instant, that is to say, it remains in this position in such a way that it cannot be displaced in a direction to build up pressure. As a result of the valve control, the forces acting upon the auxiliary piston 5 at the same time separate the latter from the working piston 22, and the piston 5 displaces the thrust rod 24.1 further to the left to increase the pressure until the control requirement "reduction of pressure" occurs and, after corresponding change-over of the valves, the auxiliary piston 5 returns towards the working piston to reduce the pressure in the brake circuit, possibly until it again comes into abutment against the working piston. Hence, the auxiliary piston is axially displaced to build up and reduce pressure alternately in accordance with the control requirements. Hence, with an average range of modulation, the required pressure modulation is effected exclusively by means of the auxiliary piston 5. It is only when the pressure has to be reduced to a value below the value assumed at the commencement of the control cycle that the working piston 22 is again used for pressure modulation by being pulled further back by corresponding change-over of the valves of the first valve unit 7. It is clear that this device always adjusts itself to the lowest μ-value of the roadway on the basis of the pedal travel.

In order to realise this mode of operation with respect to control technology, the first valve unit 7 of the anti-skid control device can, in principle, be constructed and/or operated in a very different manner, this also applying to Fig. 1.

Hence, for example, for the purpose of reducing pressure at the commencement of an anti-skid control cycle (when, in contrast, of course, to the illustration of Fig. 2, the working piston 22, together with the thrust rod 24.1 and the auxiliary piston 5, does not assume its rest position prevailing when the brake is released, but has been displaced into the valve housing), it is necessary only to change over the two valves 72.1 and 73.1, whereas the other valves of the first valve unit 7 remain in their illustrated switching states. In this switching combination, the pressure of the pump 31 or of the pressure accumulator 32 would take effect in the first component chamber 29.1 by way of the open valve 73.1, so that the auxiliary piston 5 can push the working piston 22 back in a desired manner.

The pressure medium located in the second component chamber 29.2 then flows into the reservoir 33 by way of the open valve 72.2. The pressure medium located in the working chamber 28 at the same time flows into the second return-flow chamber 29.2 by way of internal control ports, and then into the reservoir 33 by way of the open valve 72.2. If it appears advisable to reduce the pressure more rapidly, it would also be possible to switch off the brake force booster entirely in such a way that the valve 71 is shut off and the valve 74 is simultaneously opened, again until the control requirement "build up of pressure" occurs.

For the purpose of building up pressure, the valves 71 and 74 would again be controlled into their illustrated switching positions and the valve 72.2 would at the same time be closed, whereas the two valves 72.1 and 73.1 would be changed over to their illustrated switching positions again, so that pressure medium can flow into the reservoir 33 from the first component chamber 29.1, whereby the forces then acting upon the auxiliary piston 5 displace the latter to the left in a desired manner to build up pressure in the brake circuit.

The valve connections of the first valve unit 7 shown in the drawings are only illustrated by way of example. However, the basic principle of the invention can also be realised with valve connections differing from those illustrated. Hence, for example, it is possible to connect the valve 74 of Fig. 2 to the reservoir 33 by way of the valve 72.2 and not directly thereto, and at the same time to omit the valve 73.2. On the one hand, the pressure medium could then be discharged into the reservoir 33 from the working chamber 28 with the valves 72.2 and 74 open and, on the other hand, system pressure could be admitted into the second return-flow chamber 29.2 by way of the valve 74 and the working chamber 28 with valve 74 open and valve 72.2 closed.

It will be appreciated that safety valves or the like, through which the pressure medium can be discharged from the individual chambers when necessary, are conventionally provided in addition to the valves illustrated.

CLAIMS

1. An hydraulic brake system for motor vehicles having an anti-skid control device, comprising a master brake cylinder op rated by a first pressure medium, and a brake force booster which acts mechanically upon the master brake cylinder and which is operated by a second pressure medium and is operable as a pressure modulator for the anti-skid control, a respective shut-off valve being provided in each of the brake lines leading from the master brake cylinder to the wheel brake cylind rs, wherein a) the brake force booster is an hydraulic brake force booster having a pressure line connection which is connectible to an hydraulic pressure source, and at least one return-flow line connection which is connectible to a reservoir and which additionally has an auxiliary connection connected to its working-chamber, (b) the pressure modulation during anti-skid control is produced on the one hand by the working piston of the brake force booster and, on the other hand, by a modulation element which is independent thereof, (c) in the case of an average range of modulation (magnitude of the changes in pressure), the pressure modulation is substantially exclusively effected by the modulation element, while the working piston is retained in its axial position in such a way that it is not displaceable in a direction to build up pressure, and (d) in the case of greater than average changes in pressure which may be required, the working piston is also axially displaceable in conformity with the control requirements.

2. An hydraulic brake system as claimed in claim 1, wherein the modulation element is a piston and cylinder unit which is separate from the brake force booster and whose axially displaceable piston sub-divides a cylindrical chamber into a modulation chamber which is filled with the first pressure-medium and which communicates with one of the brake circuits fed by the master brake cylinder, and a working chamber which, in conformity with the control requirements, is connectible either to the pressure source or to the reservoir by way of a respective shut-off and opening valve.

3. An hydraulic brake system as claimed in claim 2, wherein, when in its state ready for operation, the working chamber communicates with the pressure source by way of the shut-off valve, and the piston thereby remains, against the action of a spring device, in a position in which the modulation chamber has its smallest volume.

4. An hydraulic brake system as claimed in any of claims 1 to 3, wherein the pressure line connection is connected to the pressure source by way of a shut-off valve, the auxiliary connection is connected to the reservoir by way of an opening valve, and the return-flow line connection is connected on the one hand to the reservoir by way of a shut-off valve and, on the other hand, to the pressure source by way of an opening valve.

5. An hydraulic brake system as claimed in claim 1, wherein the modulation element is an auxiliary piston which is subjectable to pressure at both ends and which, disposed within the return-flow chamber of the brake force booster to sub-divide the said return-flow chamber into a first and a second component chamber, is rigidly secured to the thrust rod which is effective between th working piston of the brake force booster and the master

brake cylinder ahd which is separate from but abuts axially against the working piston.

6. An hydraulic brake system as claimed in claim 5, wherein the pressure line connection is connected to the pressure source by way of a shut-off valve, the auxiliary connection is connected to the reservoir by way of an opening valve, and the return-flow line connections of the first and second component chambers are each connected on the one hand to the reservoir by way of a respective opening valve and, on the other hand, to the pressure source by way of a respective opening valve.

7. Hydraulic brake systems for motor vehicles having an anti-skid control device substantially as herein described with reference to and as illustrated in the accompanying drawings.

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